7.7 DIFFRACTION AND REFRACTION OF SOUND WAVES

PRACTICE

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Understanding Concepts

1. Diffraction describes the ability of sound waves to move around an obstacle or to spread out after going through a small opening.
2. Sound waves refract, or change their direction, when they move at an angle from air at one temperature to air at a different temperature.
3. Lower frequency sound waves have long wavelengths compared to the openings that they encounter and diffract more than higher frequency sound waves, which have shorter wavelengths.

Section 7.7 Questions

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Understanding Concepts

1. The sound waves from the woofer will be easier to hear through an open doorway. These sound waves have a lower frequency and longer wavelengths, and thus can diffract more than the higher frequency (shorter wavelength) sound waves from the tweeter.
2. A high pitch sound has a higher frequency and a shorter wavelength than a low pitch sound (low frequency and longer wavelength). Thus, a low pitch sound would diffract more and be easier to hear.

Applying Inquiry Skills

3. Noise barriers primarily reflect the sound. Some of the sound energy is diffracted over the top of the barrier. Where there is space, earth berms are effective sound barriers particularly when planted with bushes and trees. The sound is reduced by multiple reflections in the bushes and trees. As well, the amount of noise diffracted over the top is diminished.

Making Connections

4. (a) Barriers affect highway noises of differing frequencies by diffracting lower frequency sound waves (longer wavelengths) more than high frequency sounds. Thus, the noise of a brake squeal would be reduced, but low pitch truck noises would not be reduced as much.
   (b) It is not feasible to install barriers on all roads because it would be costly and would make the area unattractive, except to the residents immediately behind the barriers.
   (c) Various answers could include suggestions to make the barrier of materials that absorb sound, such as fibreglass, rather than materials that reflect sound. Could also put plants and trees around barriers to help reflect and diffract sound.

7.8 THE INTERFERENCE OF SOUND WAVES

Investigation 7.8.1 Interference of Sound Waves from a Tuning Fork and Two Loudspeakers

(Pages 261–262)

Purpose

The purpose of this investigation is to study the interference of sound waves produced by two sources of sound.

Question

Where are the areas of destructive interference located in the area surrounding the prongs of a tuning fork? Where are they located in the areas in front of two loud speakers producing identical sound waves?

Hypothesis/Prediction

(a) Having studied interference patterns of water waves from two sources in a ripple tank, it would be reasonable to assume that similar patterns would develop in the areas surrounding a tuning fork and in the areas in front of two loudspeakers producing identical sound waves. Each prong of the tuning fork and each speaker act a source of sound waves. Areas of

both constructive and destructive interference should be evident in the space around the tuning fork and in front of the two loud speakers.

Design

In the first part of this investigation a tuning fork was struck and held near the ear of the observer. By slowly rotating the tuning about its handle, the observer was able to hear both constructive and destructive interference. In the second part of this investigation, two loudspeakers produced identical sound waves. The observers walked along a line in front of and parallel to the line of the loudspeakers noting areas of constructive and destructive interference.

Materials

- tuning fork
- rubber hammer or rubber stopper
- amplifier
- audio generator
- two identical loudspeakers

Procedure

1. In a large open space, a tuning fork was struck and held vertically near the ear of the observer. It was then slowly rotated around the axis of its handle and the observer noted the areas of constructive and destructive interference. Constructive interference areas were loud whereas areas of destructive interference were nearly silent.
2. An amplifier, generator, and speakers were set up with the two speakers facing out into the room. The speakers were placed approximately 2.0 m apart and 1.0 m above the floor. Assuring the speakers were in phase, a frequency of 500 Hz was producing by the generator and played over the speakers with a moderate intensity level.
3. The observer slowly walked along a path parallel to the speakers and noted positions where the intensity was least.
4. The frequency of the generator was increased slightly and step 3 repeated.

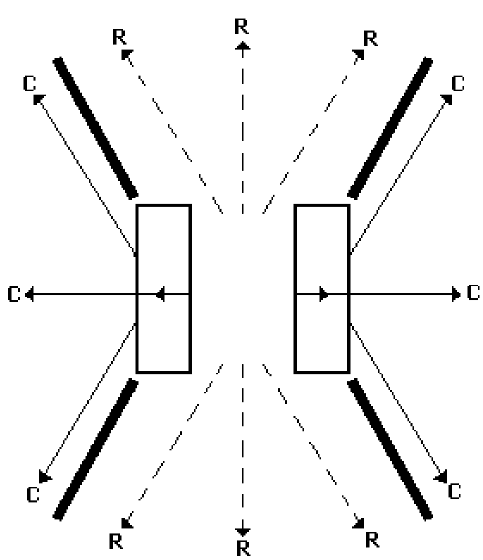
Observations

When the tuning fork was struck and slowly rotated as described the observer noted four distinct areas of relative silence and four areas of relative loudness around the tuning fork. A diagram of the pattern can be found in the analysis section (**Figure 1**).

When the observer walked along the line parallel to the loudspeakers, distinct regions of relative silence and others of relative loudness were noted by the observer. When the frequency of the generator increased, the same pattern of different intensities was noted but they were positioned closer together. (See **Figure 2**.)

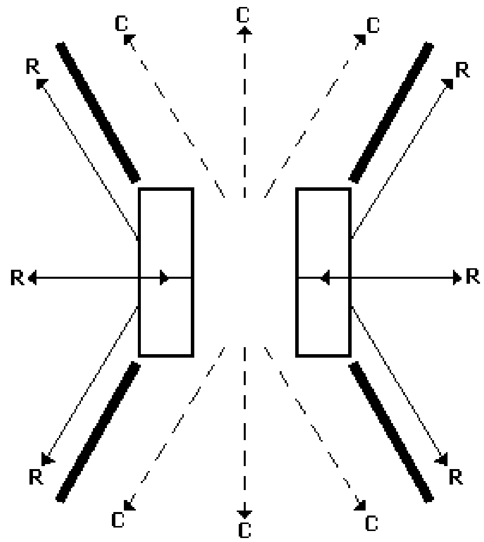
Analysis

(b) The patterns produced by the sound sources were analyzed, having applied theoretical considerations and prior learning involving patterns of water waves produced in a ripple tank.



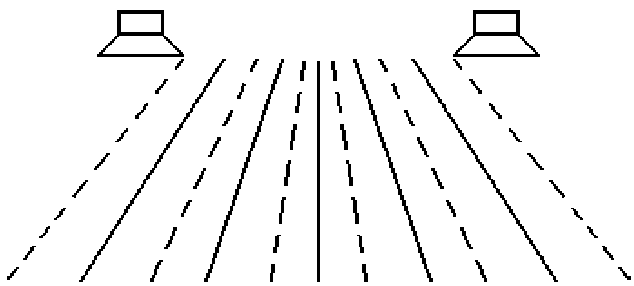
As the two prongs of the tuning fork move apart, compressions are created in the regions indicated (**C**) on the diagram. As well, an area of rarefaction (**R**) is created between the prongs. The compressions move away from the tuning fork in the directions indicated. As air moves into the rarefied area between the prongs, the rarefaction effectively moves outward in the directions indicated. Along the corners of the tuning fork, a compression meets a rarefaction producing destructive interference which is heard as relative silence. These areas are noted on the diagram as thick lines emanating from the corners.

Figure 1(a)
Patterns of Interference Surrounding a Tuning Fork
(two prongs moving apart)



As the two prongs of the tuning fork move together, rarefactions are created in the regions indicated (**R**) on the diagram. As well, an area of compression (**C**) is created between the prongs. The compressed air moves away from the tuning fork in the directions indicated. As air moves into the rarefied areas, the rarefaction effectively moves outward in the directions indicated. Along the corners of the tuning fork, a compression meets a rarefaction producing destructive interference which is heard as relative silence. These areas are noted on the diagram as thick lines emanating from the corners.

Figure 1(b)
Patterns of Interference Surrounding a Tuning Fork
(two prongs moving together)



As two loud speakers produced the same frequency a series of lines of constructive and destructive interference were produced in the area in front of the loud speakers as illustrated in the diagram. The solid lines represent areas where the sound was relatively loud (constructive interference) and the dashed lines indicate areas where the sound was relatively silent (destructive interference).

Figure 2
Interference Patterns Produced by Two Speakers

(d) When the frequency of the generator was increased the same pattern was evident but the lines of constructive and destructive interference were noted to be closer together and more numerous.
This is in keeping with the patterns of interference produced by two sources in a ripple tank. A series of nodal lines was noted in the ripple tank representing areas of destructive interference, a crest meeting (and cancelling) the influence of a trough. With the two speakers producing identical sound waves, a compression was meeting a rarefaction along these nodal lines. Also in keeping with the ripple tank observations; when the frequency of the wave generator increased, more nodal lines were noted in the pattern with the spacing between them having decreased. This was also observed with the two speakers producing higher frequency sound waves.

Evaluation

(e) The results of this investigation were well predicted by the hypothesis. The interference patterns produced by the tuning fork and by the two speakers were as expected.

(f)-(g) Since no measurements were made, the sources of experimental error were few and only of a qualitative nature. The regions of relative loudness and silence were quite apparent in both parts of this investigation. It should be noted that it is important to perform this investigation in a wide-open area to minimize the effects that reflections could have on the observations.

PRACTICE

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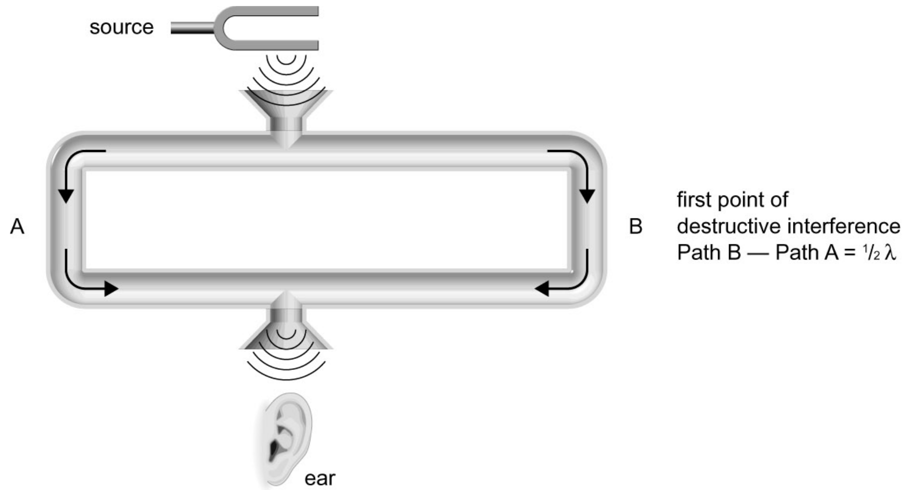
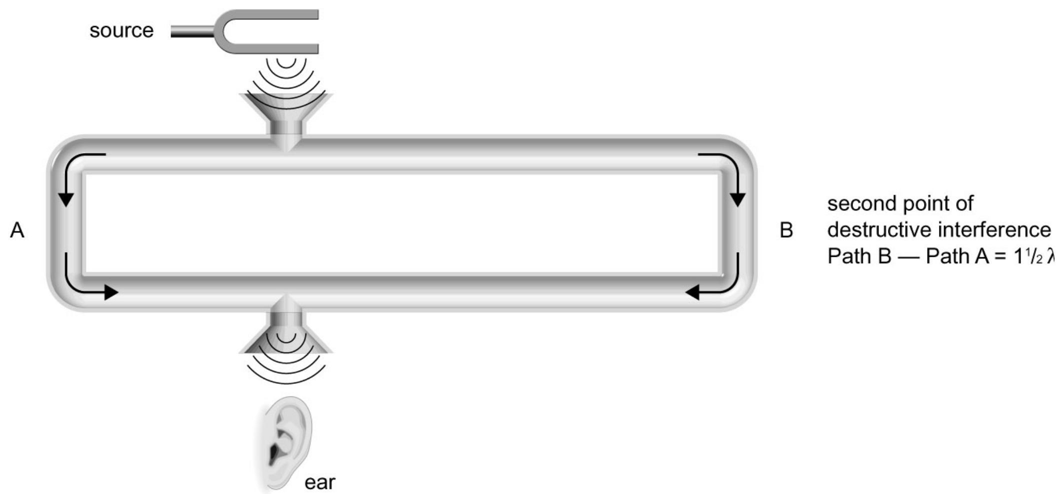
Understanding Concepts

1. There are loud and soft sound intensities in the area around a tuning fork that correspond to the constructive interference that occur because the fork times are out of phase. When the tuning fork is rotated near the ear, the sound intensity alternates between loud (constructive interference) and soft (destructive interference). Refer to Figure 1 page 261.

2.





3. Areas of constructive interference are located symmetrically about the point midway between the speakers. When two speakers are in phase, a line of constructive interference occurs at the midpoint line. This occurs because each position on the line is equidistant from both sources.

Section 7.8 Questions

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Understanding Concepts

1. The speakers should be in phase so that both speakers move in and out at the same time. If the connections are reversed, the speakers will be out of phase; while one speaker is producing a rarefaction, the other is producing a compression. When the two waves interfere, destructive interference occurs.
2. Constructive interference occurs when a compression overlaps a compression or a rarefaction overlaps a rarefaction for maximum sound intensity. Destructive interference of sound occurs when a compression merges with a rarefaction to produce minimum sound intensity.

Making Connections

3. (a) "Dead spots" are areas where destructive interference occurs. These spots occur because the sound is reflected causing destructive interference at that location. A typical example is under the balcony in a concert hall.
   (b) Engineers eliminate "dead spots" by using carefully placed reflectors to ensure that the sound reaches all locations in the hall and by using surfaces that reduce reflection (refer to Section 8.9).